

PAT. APPL.
IN-24
8523
NASA CASE NO. LAR 15094-1

PRINT FIG. 1
P-18

NOTICE

The invention disclosed in this document resulted from research in aeronautical and space activities performed under programs of the National Aeronautics and Space Administration. The invention is owned by NASA and is, therefore, available for licensing in accordance with the patent licensing regulations applicable to U.S. Government-owned inventions (37 CFR 404.1 et seq.).

To encourage commercial utilization of NASA-owned inventions, it is NASA policy to grant licenses to commercial concerns. Although NASA encourages nonexclusive licensing to promote competition and achieve the widest possible utilization, NASA will provide the necessary incentive to the licensee to achieve early practical application of the invention.

Address informational requests for this invention to the **Technology Applications Team, NASA Langley Research Center, Code 200, Hampton, Virginia 23681-0001.**

Address applications for license to the **Patent Counsel Office, Mail Stop 212, 3 Langley Boulevard, Hampton, Virginia 23681-0001.**

Serial No.: 08/416,599
Filed: 04/04/95

LaRC

CARBON-CARBON CYLINDER BLOCK

AWARDS ABSTRACT

The cylinder block of internal combustion engines in automobiles is typically made of cast iron because of the need for high mechanical strength. Use of cast iron, however, adds weight to the engine and results in lower fuel economy. In an effort to reduce engine weight, various light-weight alloys such as aluminum have been used to fabricate the cylinder block. Alloys such as aluminum, however, have lower mechanical strength than cast iron and thus result in undesirable vibration. In addition, aluminum alloys have a lower temperature resistance and higher coefficient of thermal expansion than cast iron.

The carbon-carbon cylinder block represents a great improvement in the prior art. While performing the same function as a cast iron or aluminum alloy cylinder block, a carbon-carbon cylinder block has lower weight and negligible coefficient of thermal expansion (CTE), over 40 times smaller than that of aluminum, thereby resulting in higher dimensional stability at operating temperatures. The lower CTE of the carbon-carbon cylinder block, when used in conjunction with a carbon-carbon piston or other piston with very low CTE, results in the ability to use ringless pistons.

Novel aspects of the present invention include the use of carbon-carbon to fabricate cylinder blocks and the use various architectures for forming the cylinder blocks.

Inventor: Philip O. Ransone
Address: 1325 Laurens Road
Gloucester Point, VA 23062
ss: [REDACTED]
Employer: NASA LaRC
Initial Evaluator: Howard G. Maahs

Serial No.: 08/416,599
Filed: April 4, 1995

CARBON-CARBON CYLINDER BLOCK

Origin of the Invention

5 The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

10 Background of the Invention1. Field of the Invention

 This invention relates generally to a cylinder block and a method of
15 making a cylinder block for internal combustion engines, and more particularly to a carbon-carbon cylinder block that is lightweight, temperature resistant and has a low coefficient of thermal expansion.

2. Description of the Related Art

20

 The cylinder block of internal combustion engines in automobiles is typically made of cast iron because of the need for high mechanical strength. Use of cast iron, however, adds weight to the engine and results in lower fuel economy. In an effort to reduce engine weight,
25 various light-weight alloys such as aluminum have been used to fabricate the cylinder block. Alloys such as aluminum, however, have lower mechanical strength than cast iron and thus result in undesirable vibration. In addition, aluminum alloys have a lower temperature resistance and higher coefficient of thermal expansion than cast iron.

Summary of the Invention

Carbon-carbon is of considerable interest in the fields of aeronautics and aerospace where resistance to high temperatures and thermal shocks, coupled with high strength is important. The carbon-carbon cylinder block represents a great improvement in the prior art. While performing the same function as a cast iron or aluminum alloy cylinder block, a carbon-carbon cylinder block has lower weight and negligible coefficient of thermal expansion (CTE), over 40 times smaller than that of aluminum, thereby resulting in higher dimensional stability at operating temperatures. The lower CTE of the carbon-carbon cylinder block, when used in conjunction with a carbon-carbon piston or other piston with very low CTE, results in the ability to use ringless pistons.

Accordingly an object of this invention is to reduce the cylinder block weight in an internal combustion reciprocating engine with the use of a carbon-carbon cylinder block.

It is another object of the present invention to provide a cylinder block with adequate mechanical strength during operation of the engine.

Another object of the invention is to provide a cylinder block with a low coefficient of thermal expansion, resulting in lower distortion and higher dimensional stability.

According to the present invention, the foregoing and additional objects are attained by providing a carbon-carbon cylinder block having at least one cylinder bore. The carbon-carbon block can be fabricated from a variety of multi-dimensional architectural arrangements in which the fibers are perpendicular to the axis of the cylinder bore. This fiber orientation takes advantage of the high thermal conductivity of carbon-carbon along the length of the fiber. Carbon-carbon is lightweight, temperature resistant and possesses a low coefficient of thermal

expansion. Therefore, the cylinder block has greater dimensional stability and, when used with pistons having very low coefficients of thermal expansion, this stability precludes the need for piston rings and results in improved engine efficiency and lower levels of emissions due to close
5 tolerances. Additional objects and advantages of the present invention are apparent by the drawings and specification which follow.

Brief Description of the Drawings

10 FIG. 1 is an exploded illustration of a carbon-carbon cylinder block resting between a metal crankcase and a metal engine head;

FIG. 2 is a cutaway illustration of a carbon-carbon cylinder block attached between a metal crankcase and a metal engine head; and

FIG. 3 is an exploded illustration of a carbon-carbon, single-bore,
15 cylinder barrel resting between a metal crankcase and a metal engine head;

FIG. 4 is a cutaway illustration of a carbon-carbon, single-bore, cylinder head with circumferential grooves;

FIG. 5 is an illustration of a carbon-carbon cylinder block formed of
20 stacked 2-D plies;

FIG. 6 is a top view of a 2-D, single ply of carbon-carbon used to fabricate a cylinder block;

FIG. 7a is an illustration of a 3-D carbon-carbon fiber architecture;

FIG. 7b is an illustration of another 3-D carbon-carbon fiber
25 architecture; and

FIG. 8 is an illustration of an uncompressed polar weave fabric for fabricating single-bore, cylinder blocks.

Detailed Description of the Invention

Referring to FIGS. 1 and 2, a carbon-carbon cylinder block **10**, constructed of carbon-fabric plies oriented perpendicular to the axis of the cylinder bore **20** or bores, is sandwiched between a liquid or air cooled metal head **30** and a metal crank case **40** where the assembly is held together by long head bolts **50** which pass through the head **30** and the carbon-carbon block **10**. Alternatively, the bolts **50** may pass along the outside of the cylinder block **10** and thread into the metal crank case **40**. The carbon-carbon block **10** can be sealed to the crank case **40** with an O-ring-type seal (not shown) and to the head **30** with an appropriately designed head gasket (not shown).

Since the thermal conductivity of the carbon fibers, several times greater than that of copper is possible, it is anticipated that liquid cooling passages in the automotive carbon-carbon block would not be required as the high thermal conductivity of the carbon fibers can be taken advantage of to conduct heat away from the cylinder bores to the exterior surfaces of the block where it can be disposed by convection. Metal tubes or jackets can be brazed to the exterior surfaces of the carbon-carbon block as required to circulate liquid coolant around the exterior of the block.

Referring to FIG. 3, for the air cooled engine where a relatively thin-walled cylinder block **10** having a single bore **20** is employed, the heat must be conducted over a much shorter distance to be dissipated to the air being forced past the block **10**. Since the heat is primarily being transported along the length of the fiber, a fin arrangement will not be needed for the purpose of cooling. The side surfaces of a fin should not contribute enough to heat dissipation to be a significant cooling factor because of the relatively poor radial thermal conductivity of carbon

fibers. However, as illustrated in FIG. 4, to provide structural strength, circumferential grooves 80 may be machined into the cylinder block 10 and carbon fiber tows (not shown) may be wound in the grooves to produce hoop strength.

5 In either the single or multiple bore cylinder block configuration the heat input to the cylinder walls should be lower when used with a low CTE ringless piston because of the absence of ring friction. Also, the combination of a low CTE and a higher allowable operating temperature for a carbon-carbon piston and the carbon-carbon block should make
10 heat removal for the purposes of controlling piston temperatures and thermal distortions less critical than is the case for aluminum alloy pistons and cylinder block materials where the CTEs are relatively high.

There are a number of reinforcement architectural arrangements (e.g., 2-D, 3-D, ...n-D) whereby a carbon-carbon cylinder block 10 can
15 be constructed, however, the simplest and most economical construction is illustrated in FIGS. 5 and 6 and would consist of a stack of 2-D fabric plies 90 where all the fibers 100 are perpendicular to the axis of the cylinder bore 20. This arrangement is the basis for the close-tolerance piston-to-cylinder clearance engine. It takes maximum advantage of two
20 very attractive features offered by carbon fibers for this application; namely, their high axial thermal conductivity and nearly zero axial thermal expansion. Maximum thermal conductivity will be normal to the cylinder bores 20 in this arrangement which should produce the most efficient cooling. The CTE of a carbon-carbon fiber is essentially zero in the axial
25 direction but slightly higher in the radial direction. The effect of radial expansion of the fibers on pistons will be difficult to entirely avoid because low tensile strength of the composite perpendicular to the fiber directions will dictate that at least some reinforcement be in each orthogonal direction of the piston. Therefore, the piston may be subject

to some diametral thermal growth.

To minimize this thermal growth, the use of circumferentially or axially oriented fibers should be minimized in piston designs. However, the effect of the fiber radial expansion on cylinder bore dimensions can be avoided using the preferred 2-D arrangement to construct the block. If a significant fraction of fibers were in the z-direction of the composite containing the cylinder bore or were circumferential to the surface of the bore, thermal growth of the composite could result in a decrease in the bore diameter. Additional clearance between the piston and cylinder would be required to accommodate this dimensional change. Use of the preferred 2-D arrangement will insure that dimensional changes in the bore due to thermal effects will be absolutely minimized. If growth of the bore diameter should occur as a result of the fact that carbon fibers have a slightly negative axial CTE at temperatures falling within the range of engine operating temperatures, this can be offset by adding fibers in the axial direction of the piston to cause the desired thermal growth of the piston diameter. Holding the clearances between the piston and cylinder wall to the absolute minimum is essential to success of the ringless piston engine and the described reinforcement architecture offers the most potential for achieving this goal. The inherently low interlaminar strength of a carbon-carbon block of this architecture is not a major concern, because the clamping force of the head bolts would negate cross-ply tensile stresses in the laminate. Although the stacked 2-D ply arrangement is preferred, other multi-dimensional fiber arrangements can be used, such as the 3-D fiber arrangements illustrated in FIGS. 7a and 7b.

For the single bore cylinder block 10 as illustrated in Fig. 3, a laminated polar weave architecture, as illustrated in FIG. 8, with a spiral laminate 120 having radial 140 and circumferential 130 fiber tows may

be used to increase hoop strength. In addition, for the case of the single-bore cylinder block 10 as illustrated in FIG. 3, a reinforcement architecture may be used in which most of the fibers are oriented parallel and circumferential to the bore axis. This is possible because heat
5 moves across a much shorter distance than in the cylinder block illustrated in FIG. 1. Such architecture can be produced by rolling 2-D fabric into a tube and molding or by molding a 3-D braided tube or by building up layers of 2-D braided tubes and molding.

To make a carbon-carbon composite engine block, carbon fibers
10 are selected having the desired properties such as fiber thermal conductivity and desired strength and modulus. Fiber tows are then woven into 2-D fabrics or 3-D preforms, such as 2-D orthogonal, triaxial, or polar weaves or 3-D orthogonal weaves, angled interlock weaves or needled felts. The carbon preforms or fiber fabrics are heat treated as
15 required to condition fiber surfaces and/or obtain other desired properties such as modulus or thermal conductivity. The fabrics are then prepregged with a suitable high carbon-yielding resin such as phenolic resin, which may contain carbon-based fillers to reduce shrinkage or may contain particulate or molecular additives to inhibit oxidation or enhance
20 other properties such as thermal expansion in the finished part. The plies of prepregged 2-D carbon fabrics, which may be all of the same weave architecture or of different weave architecture, are then stacked. A carbon fiber 3-D preform of an appropriate architecture may also be used. The 2-D stack of plies is then molded and cured and the molded
25 part is pyrolyzed in an inert atmosphere. The 3-D preform is infiltrated with a suitable filled or unfilled resin or pitch system, such as mesophase pitch or pitch resin mixtures, and pyrolyzed in an inert atmosphere. The initially carbonized part is then densified with carbon by any or a combination of available methods including resin (or pitch) reimpregnation

and carbonization and chemical vapor infiltration processes using hydrocarbon gases or liquids as carbon sources. Desired thermal conductivity and other desired properties such as modulus are obtained by post-process heat treating in an inert atmosphere to temperatures of
5 approximately 2500°C or higher . The cylinder bores are then finish machined and oxidation-protective and/or wear-resistant coatings are applied to the cylinder walls.

To facilitate densification processing of 2-D carbon-carbon composites of such thickness, the rough cylinder bore can be molded
10 into the barrel. The rough bores can also be molded into block or can be machined in before initial carbonization. In either case, this fabrication strategy exposes the central-most plies of the layup to the impregnating materials during the densification steps.

After machining of the cylinder bores to near final diameter, the
15 cylinder wall surfaces are treated, using appropriate sealing/coating processes, to produce the necessary oxidation protection and desirable friction characteristics before final honing.

The schematic diagram of FIG. 1 for the liquid-cooled application depicts a 4-cylinder in-line arrangement, but any other arrangement of 1,
20 2, 3, ...n cylinders (as in a V8) is envisioned. Likewise, for the air-cooled application, any arrangement of cylinders about the crankcase (as in 180° opposing or radial) is envisioned.

Many modifications, improvements and substitutions will be apparent to the skilled artisan without departing from the spirit and scope
25 of the present invention as described in the specification and defined in the following claims.

What is claimed is:

"Page missing from available version"

"Page missing from available version"

CARBON-CARBON CYLINDER BLOCK

Abstract of the Disclosure

5 A lightweight cylinder block composed of carbon-carbon is disclosed. The use of carbon-carbon over conventional materials, such as cast iron or aluminum, reduces the weight of the cylinder block and improves thermal efficiency of the internal combustion reciprocating engine. Due to the negligible coefficient of thermal expansion and unique
10 strength at elevated temperatures of carbon-carbon, the piston-to-cylinder wall clearance can be small, especially when the carbon-carbon cylinder block is used in conjunction with a carbon-carbon piston. Use of the carbon-carbon cylinder block has the effect of reducing the weight of other reciprocating engine components allowing the piston to run at
15 higher speeds and improving specific engine performance.

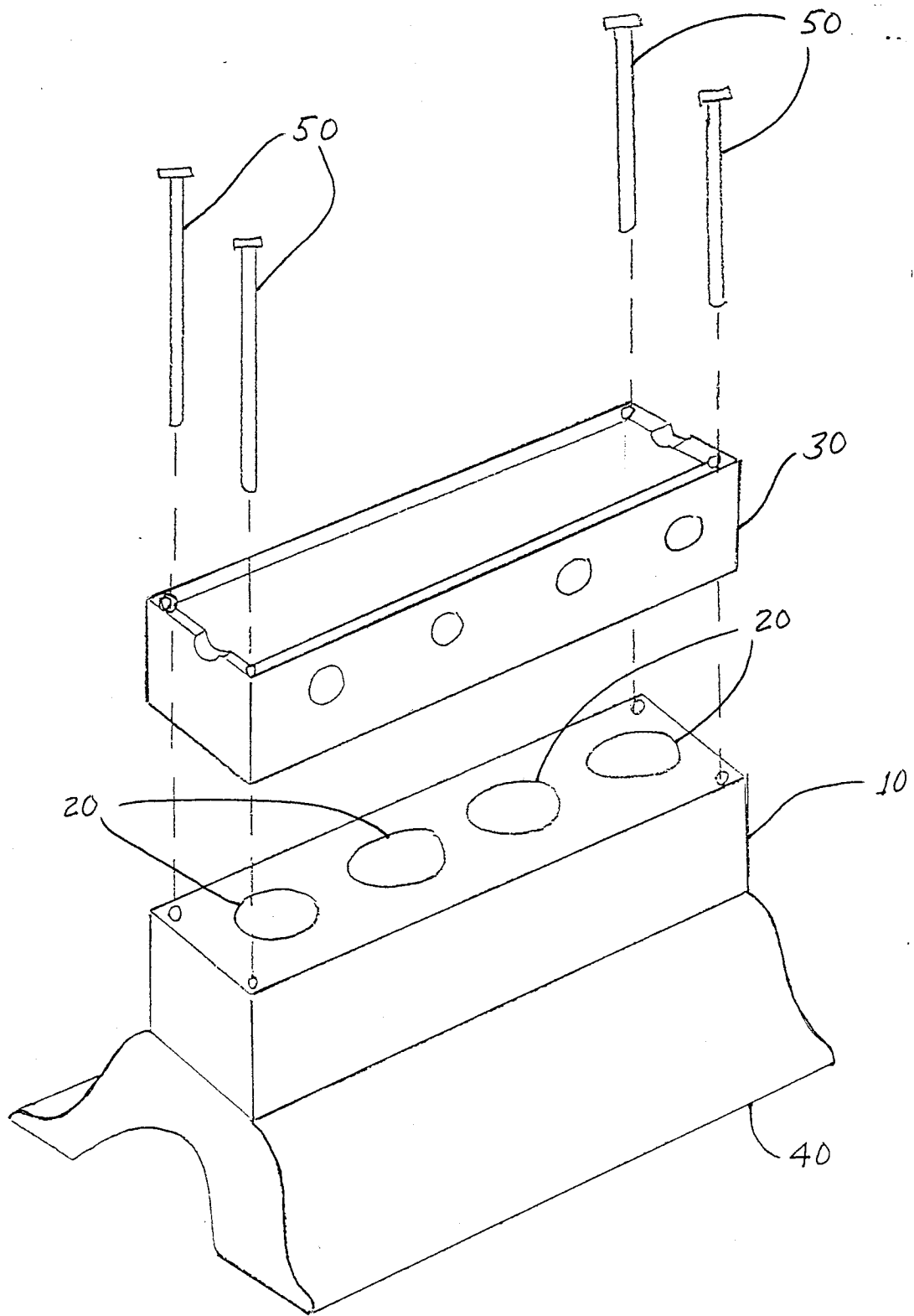


FIG. 1

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 1 OF 8

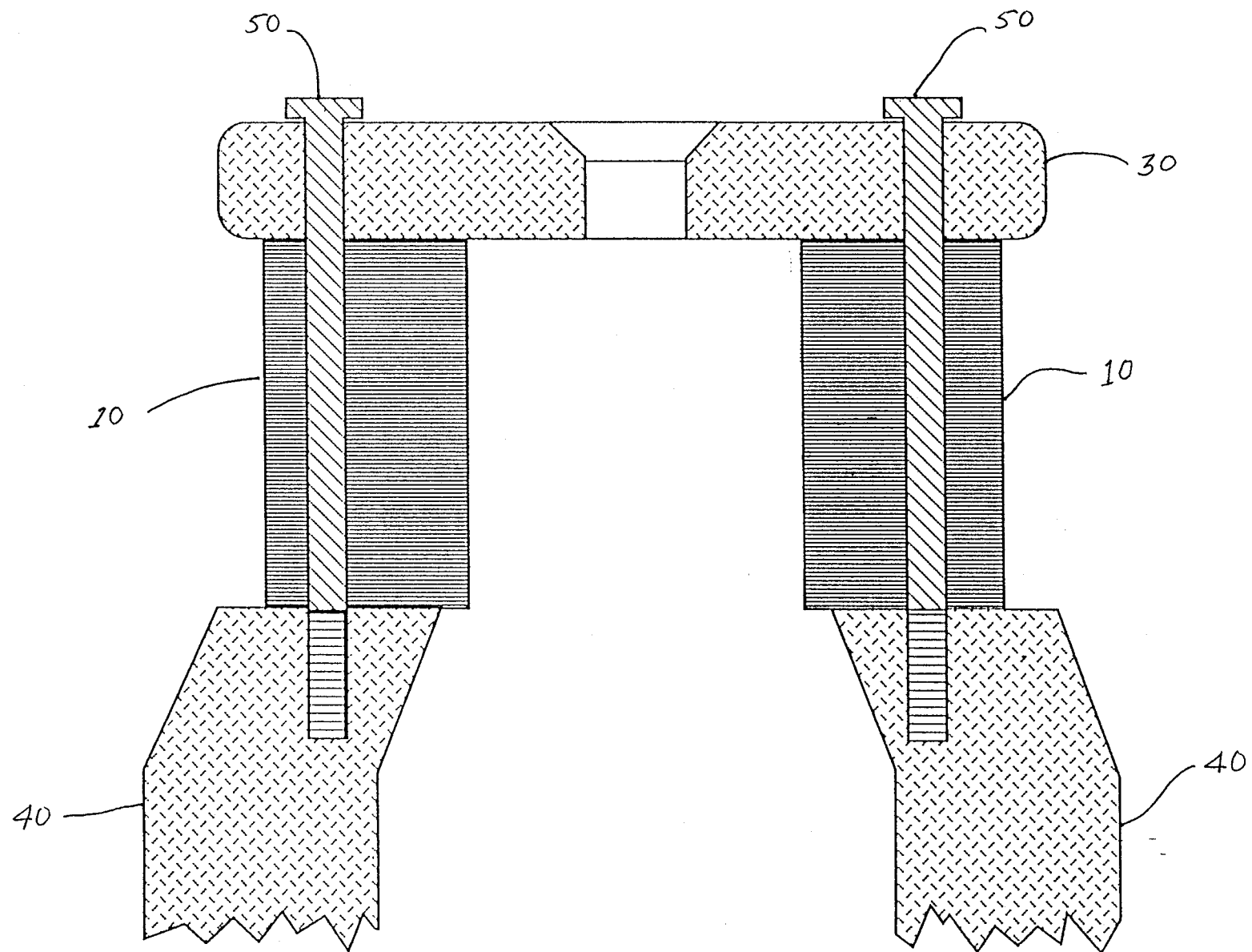


FIG. 2

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 2 OF 8

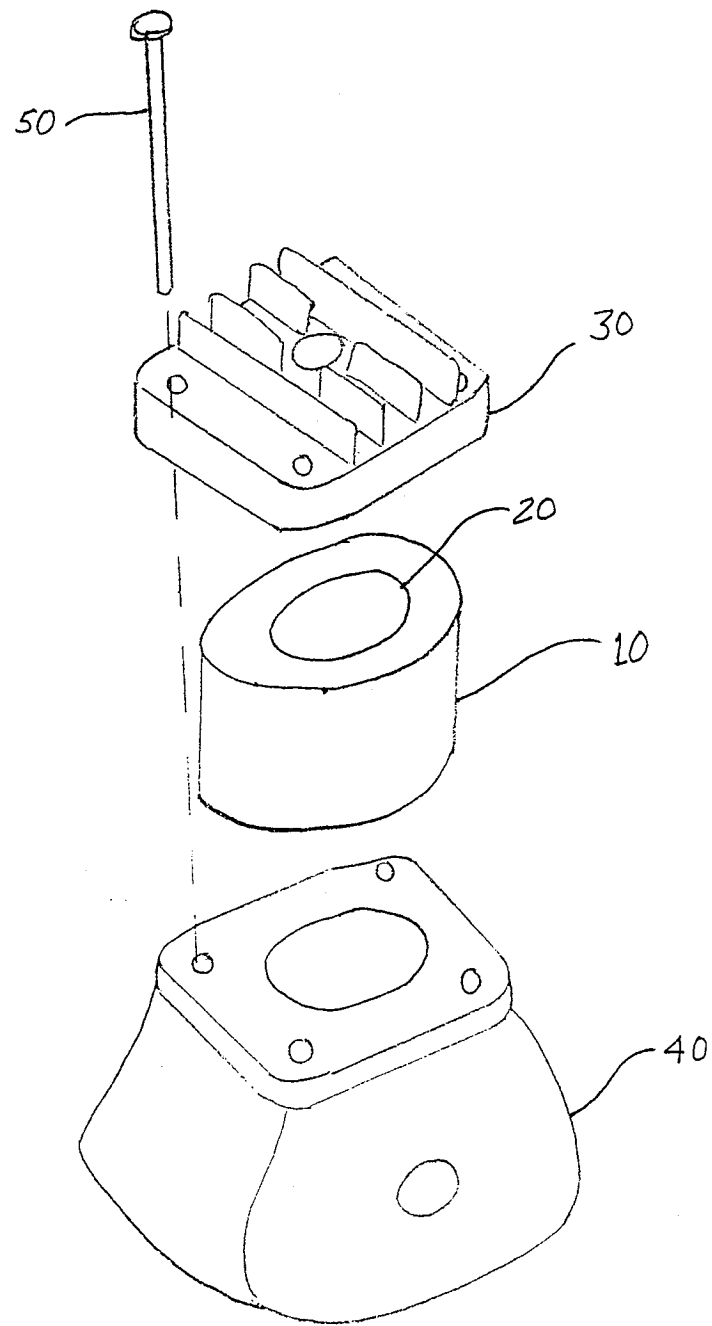


FIG. 3

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 3 OF 8

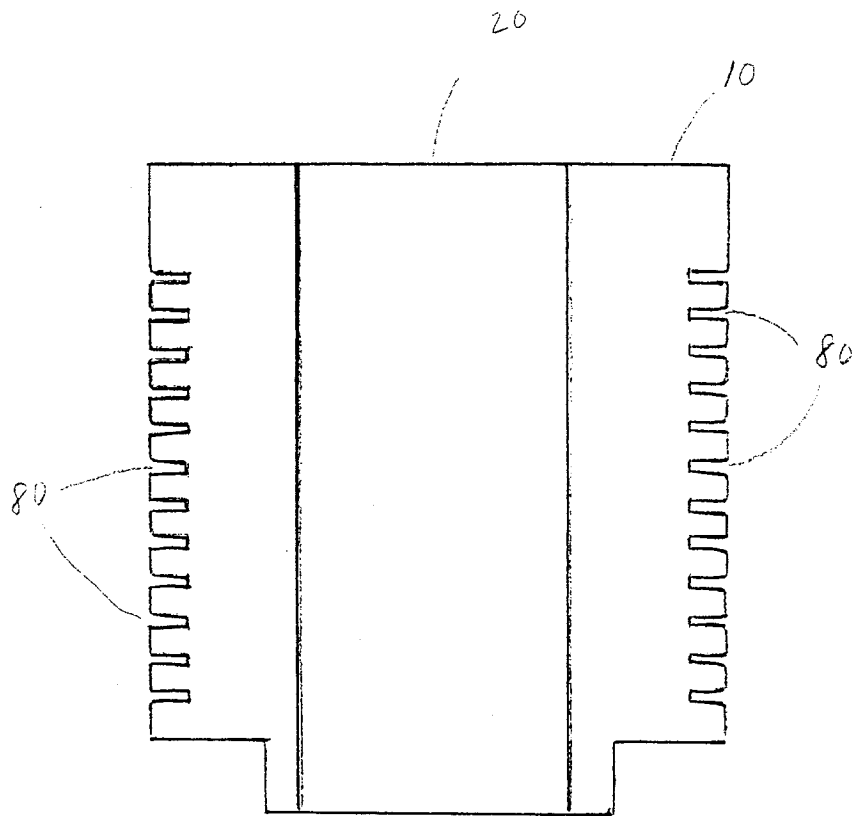


Fig. 4

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET ~~4~~ OF 8

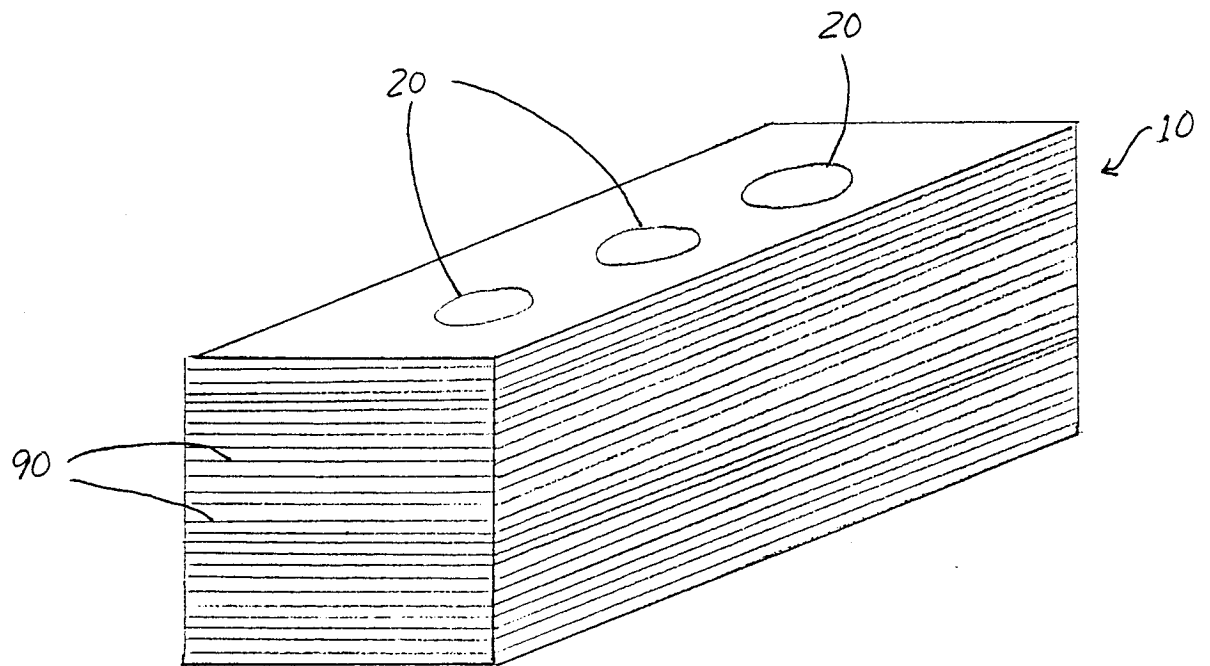


FIG. 5

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 5 OF 8

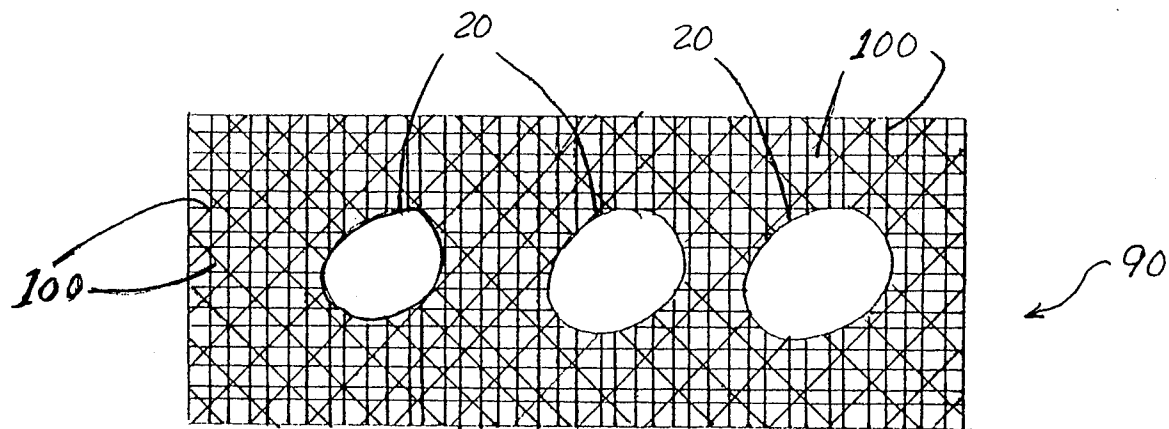


FIG. 6

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 6 OF 8

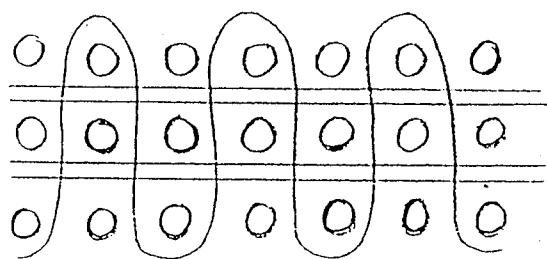


FIG. 7a

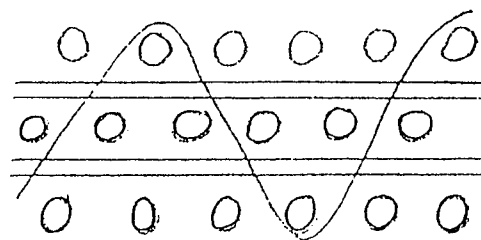


FIG. 7b

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 7 OF 8

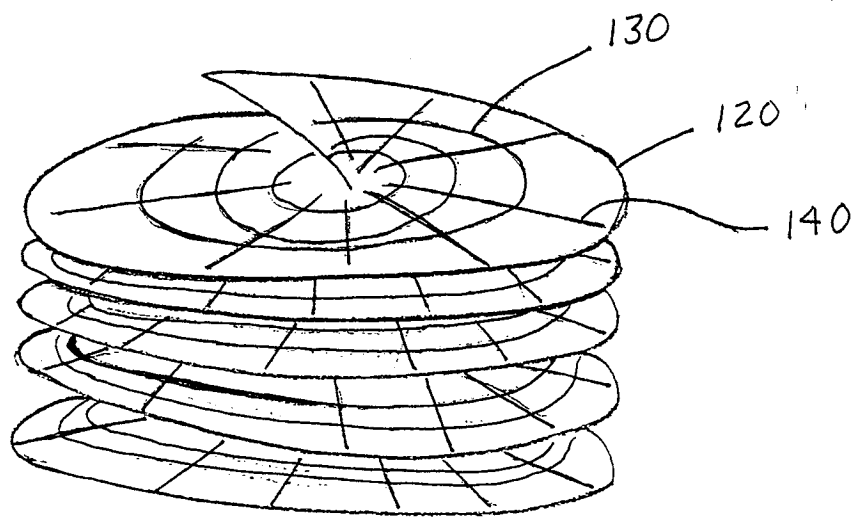


FIG. 8

NASA CASE NO LAR 15094-1
PHILIP O. RANSONE
SHEET 2 OF 8